ETH
Eidgenössische Technische Hochschule Zürich
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Distributed Computing

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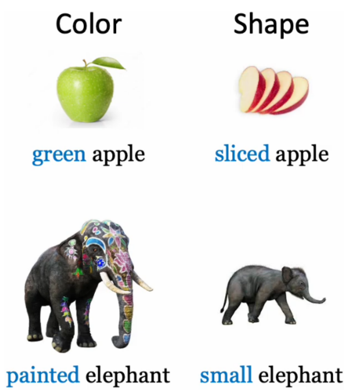
Federated Compositional Representation Learning



Compositionality is the ability of an intelligent system to combine a finite set of known "primitive" concepts into novel configurations and then understand or generate those configurations. Humans learn basic shapes and colors and then easily interpret or create new shape-colour combinations. In machine learning this is "compositional generalization": the capacity for a model to recombine learned factors (e.g., "red", "circle") in previously unseen combinations. In Federated Learning many client devices collaborate to train a shared global model without exchanging raw data, strengthening privacy. Data on each client are typically non-identically distributed (non-IID) and heterogeneous, which makes training a robust global challenging. Federated Learning allows training a global model with a big data, while respecting users' privacy.

Training a **Compositional Federated Model** is challenging because:

- Each device may see only a limited subset of the primitive concepts or combinations (for example one client sees "red circles" and another "blue squares"), therefore the shared model must learn primitives distributed unevenly across clients and still generalize to unseen combinations that no single client observed.
- Heterogeneity in concept distribution means the aggregation of client updates may dilute or entangle primitives rather than learning clean independent modules, impairing recomposition ability.
- Privacy constraints limit sharing raw data or full concept-occurrence statistics, inhibiting direct alignment of primitive representations across clients.

How to design federated learning aggregation and representation-sharing mechanisms under uneven primitive-concept coverage across users, so that the global model learns disentangled primitive concept modules that enable reliable generalization to unseen compositions of those primitives? This question targets the intersection of compositionality (learning and recombining primitives) and Federated Learning (distributed, non-IID, privacy-preserving), aiming to overcome the obstacle of uneven concept exposure across clients while maintaining privacy and global generality.

Interested? Contact us!

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